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# How Many Fish Equal A Tree?

## Evaluating Natural and Policy Constraints In NER Plan Development

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# Summary

- First Encounter “What’s the exchange rate between fish and trees?”
- Formulating and evaluating aquatic habitat outputs
- Formulating and evaluating wetland habitat outputs
- Lessons learned

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# What's the exchange rate between fish and trees?

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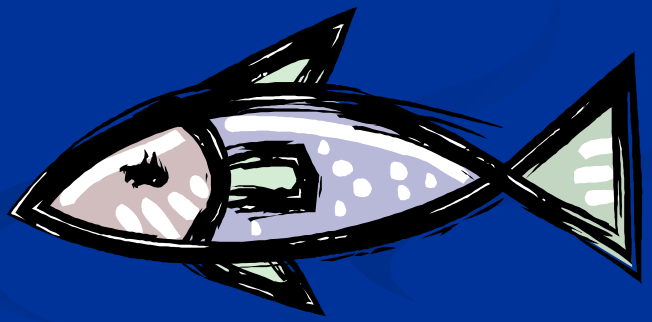

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# What's the exchange rate between fish and trees?

- Problem: There are two potentially competing uses of water (an aquatic habitat, and a wetland habitat) but

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# Formulating and evaluating aquatic habitat outputs

- Aquatic Habitat Goals
  - Increase dissolved oxygen
  - Decrease water temperature
  - Increase total habitat size
- Management Measures Considered
  - No action
  - Groundwater inflows (limited availability)
  - Aerators (surface or bottom)
  - Recirculation pumps
  - Excavate larger ponds
- Outputs Developed
  - Aquatic habitat size
  - Dissolved Oxygen
  - Water temperature
  - Composite Index

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# Formulating and evaluating aquatic habitat outputs

Benefit matrix developed by contractor. Needed to be manually entered into [illegible]

| A1 | A2 | A3 | A4 | A5 | C1 | B1 | D0 | D1 | D2 | D3 | 12120000 | E0 | | 20200000 | E1 | | 30300000 | E2 | | 40400000 | E3 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Old pumps have 200 gpm capacity ea. | | | | | | | | | | | 4.4 | DO Consumed | | 3.6 | DO Consumed | | 2.7 | DO Consumed | | 1.8 | DO Consumed | |
| Ne pumps Cost = 350K + gpm/100 | | | | | 125,969 | 0 | | | 64,823 | | | | | 8.08 | Marg. Vol. (1M gal.) | | 18.18 | Marg. Vol. (1M gal.) | | 28.28 | Marg. Vol. (1M gal.) | |
| | | | | | | | | | | | Cost = | 0 | | Cost = | $140,014 | | Cost = | $315,032 | 717,795 | Cost = | $490,050 | |
| | | | | | 193,512 | | | | Cost=358K + gpm/100 | | 6' Depth, 12,120,000 gal. Capacity | | | 10' Depth, 20,020,000 gal. Capacity | | | 15' Depth, 30,030,000 gal. Capacity | | | 20' Depth, 40,040,000 gal. Capacity | | |
| WELL WATER SUPPLY FLOW (GPM) | | | | | MECHANICAL ACTION (%) NO | BOTTOM | SURFACE | RECIRCULATION FLOW (GPM) | | | | DO AFTER MIXING IS COMPLETED | CHANGE IN TEMP. | | DO AFTER MIXING IS COMPLETED | CHANGE IN TEMP. | | DO AFTER MIXING IS COMPLETED | CHANGE IN TEMP. | | DO AFTER MIXING IS COMPLETED | CHANGE IN TEMP. | |
| 100 | 200 | 400 | 700 | 1400 | AERATION | AERATION | AERATION | NONE | 200 | 400 | 800 | | | Output* | | | Output* | | | Output* | | | Output* |
| | | | | | 0 | | | 0 | | | | 1.60 | 86.00 | 0.00 | 2.40 | 86.00 | 8.88 | 3.30 | 86.00 | 19.88 | 4.20 | 86.00 | 30.88 |
| | | | | | 0 | | | | 200 | | | 1.60 | 86.00 | 0.00 | 2.40 | 86.00 | 8.88 | 3.30 | 86.00 | 19.88 | 4.20 | 86.00 | 30.88 |
| | | | | | 0 | | | | | 400 | | 1.60 | 86.00 | 0.00 | 2.40 | 86.00 | 8.88 | 3.30 | 86.00 | 19.88 | 4.20 | 86.00 | 30.88 |
| | | | | | 0 | | | | | | 800 | 1.60 | 86.00 | 0.00 | 2.40 | 86.00 | 8.88 | 3.30 | 86.00 | 19.88 | 4.20 | 86.00 | 30.88 |
| | | | | | | 100 | | 0 | | | | 1.60 | 86.00 | 0.00 | 2.40 | 86.00 | 8.88 | 3.30 | 86.00 | 19.88 | 4.20 | 86.00 | 30.88 |
| | | | | | | 100 | | | 200 | | | 1.60 | 86.00 | 0.00 | 2.40 | 86.00 | 8.88 | 3.30 | 86.00 | 19.88 | 4.20 | 86.00 | 30.88 |
| | | | | | | 100 | | | | 400 | | 1.60 | 86.00 | 0.00 | 2.40 | 86.00 | 8.88 | 3.30 | 86.00 | 19.88 | 4.20 | 86.00 | 30.88 |
| | | | | | | 100 | | | | | 800 | 1.60 | 86.00 | 0.00 | 2.40 | 86.00 | 8.88 | 3.30 | 86.00 | 19.88 | 4.20 | 86.00 | 30.88 |
| | | | | | | | 50 | 0 | | | | 1.60 | 86.00 | 0.00 | 2.40 | 86.00 | 8.88 | 3.30 | 86.00 | 19.88 | 4.20 | 86.00 | 30.88 |
| | | | | | | | 50 | | 200 | | | 1.60 | 86.00 | 0.00 | 2.40 | 86.00 | 8.88 | 3.30 | 86.00 | 19.88 | 4.20 | 86.00 | 30.88 |
| | | | | | | | 50 | | | 400 | | 1.60 | 86.00 | 0.00 | 2.40 | 86.00 | 8.88 | 3.30 | 86.00 | 19.88 | 4.20 | 86.00 | 30.88 |
| | | | | | | | 50 | | | | 800 | 1.60 | 86.00 | 0.00 | 2.40 | 86.00 | 8.88 | 3.30 | 86.00 | 19.88 | 4.20 | 86.00 | 30.88 |
| 100 | | | | | 0 | | | 0 | | | | 2.34 | 85.79 | 0.95 | 3.62 | 85.87 | 10.23 | 4.01 | 85.91 | 20.68 | 4.91 | 85.94 | 31.65 |
| 100 | | | | | 0 | | | | 200 | | | 2.38 | 85.79 | 1.00 | 3.64 | 85.87 | 10.24 | 4.02 | 85.91 | 20.69 | 4.91 | 85.94 | 31.66 |
| 100 | | | | | 0 | | | | | 400 | | 2.43 | 85.79 | 1.04 | 3.66 | 85.87 | 10.26 | 4.03 | 85.91 | 20.70 | 4.92 | 85.94 | 31.66 |
| 100 | | | | | 0 | | | | | | 800 | 2.52 | 85.79 | 1.13 | 3.69 | 85.87 | 10.30 | 4.05 | 85.91 | 20.72 | 4.93 | 85.94 | 31.67 |
| 100 | | | | | | 100 | | 0 | | | | 2.68 | 85.79 | 1.29 | 3.76 | 85.87 | 10.37 | 4.10 | 85.91 | 20.76 | 4.95 | 85.94 | 31.69 |
| 100 | | | | | | 100 | | | 200 | | | 2.72 | 85.79 | 1.33 | 3.78 | 85.87 | 10.39 | 4.11 | 85.91 | 20.77 | 4.95 | 85.94 | 31.70 |
| 100 | | | | | | 100 | | | | 400 | | 2.76 | 85.79 | 1.37 | 3.80 | 85.87 | 10.41 | 4.12 | 85.91 | 20.78 | 4.96 | 85.94 | 31.70 |
| 100 | | | | | | 100 | | | | | 800 | 2.83 | 85.79 | 1.45 | 3.83 | 85.87 | 10.44 | 4.14 | 85.91 | 20.80 | 4.97 | 85.94 | 31.71 |
| 100 | | | | | | | 50 | 0 | | | | 2.52 | 85.79 | 1.13 | 3.69 | 85.87 | 10.30 | 4.05 | 85.91 | 20.72 | 4.93 | 85.94 | 31.67 |
| 100 | | | | | | | 50 | | 200 | | | 2.56 | 85.79 | 1.17 | 3.71 | 85.87 | 10.32 | 4.06 | 85.91 | 20.73 | 4.93 | 85.94 | 31.68 |
| 100 | | | | | | | 50 | | | 400 | | 2.60 | 85.79 | 1.22 | 3.73 | 85.87 | 10.34 | 4.08 | 85.91 | 20.74 | 4.94 | 85.94 | 31.68 |
| 100 | | | | | | | 50 | | | | 800 | 2.68 | 85.79 | 1.30 | 3.76 | 85.87 | 10.37 | 4.10 | 85.91 | 20.76 | 4.95 | 85.94 | 31.69 |
| | 200 | | | | 0 | | | 0 | | | | 2.37 | 85.57 | 1.20 | 3.63 | 85.74 | 10.37 | 4.02 | 85.83 | 20.77 | 4.91 | 85.87 | 31.72 |
| | 200 | | | | 0 | | | | 200 | | | 2.42 | 85.57 | 1.25 | 3.66 | 85.74 | 10.39 | 4.03 | 85.83 | 20.78 | 4.92 | 85.87 | 31.73 |
| | 200 | | | | 0 | | | | | 400 | | 2.46 | 85.57 | 1.29 | 3.67 | 85.74 | 10.41 | 4.04 | 85.83 | 20.79 | 4.92 | 85.87 | 31.73 |
| | 200 | | | | 0 | | | | | | 800 | 2.55 | 85.57 | 1.38 | 3.71 | 85.74 | 10.45 | 4.06 | 85.83 | 20.82 | 4.93 | 85.87 | 31.74 |
| | 200 | | | | | 100 | | 0 | | | | 2.71 | 85.57 | 1.54 | 3.78 | 85.74 | 10.52 | 4.11 | 85.83 | 20.86 | 4.95 | 85.87 | 31.76 |
| | 200 | | | | | 100 | | | 200 | | | 2.75 | 85.57 | 1.58 | 3.80 | 85.74 | 10.53 | 4.12 | 85.83 | 20.87 | 4.96 | 85.87 | 31.77 |
| | 200 | | | | | 100 | | | | 400 | | 2.79 | 85.57 | 1.62 | 3.81 | 85.74 | 10.55 | 4.13 | 85.83 | 20.88 | 4.96 | 85.87 | 31.77 |
| | 200 | | | | | 100 | | | | | 800 | 2.86 | 85.57 | 1.69 | 3.85 | 85.74 | 10.58 | 4.15 | 85.83 | 20.90 | 4.97 | 85.87 | 31.78 |
| | 200 | | | | | | 50 | 0 | | | | 2.55 | 85.57 | 1.38 | 3.71 | 85.74 | 10.45 | 4.06 | 85.83 | 20.82 | 4.93 | 85.87 | 31.74 |
| | 200 | | | | | | 50 | | 200 | | | 2.59 | 85.57 | 1.42 | 3.73 | 85.74 | 10.46 | 4.07 | 85.83 | 20.83 | 4.94 | 85.87 | 31.75 |
| | 200 | | | | | | 50 | | | 400 | | 2.63 | 85.57 | 1.46 | 3.76 | 85.74 | 10.48 | 4.09 | 85.83 | 20.84 | 4.94 | 85.87 | 31.75 |
| | 200 | | | | | | 50 | | | | 800 | 2.71 | 85.57 | 1.54 | 3.78 | 85.74 | 10.52 | 4.11 | 85.83 | 20.86 | 4.96 | 85.87 | 31.76 |
| | | 400 | | | 0 | | | 0 | | | | 2.44 | 85.14 | 1.70 | 3.67 | 85.49 | 10.66 | 4.04 | 85.66 | 20.96 | 4.93 | 85.74 | 31.86 |
| | | 400 | | | 0 | | | | 200 | | | 2.49 | 85.14 | 1.74 | 3.69 | 85.49 | 10.68 | 4.05 | 85.66 | 20.98 | 4.93 | 85.74 | 31.87 |
| | | 400 | | | 0 | | | | | 400 | | 2.53 | 85.14 | 1.79 | 3.71 | 85.49 | 10.70 | 4.06 | 85.66 | 20.99 | 4.94 | 85.74 | 31.87 |
| | | 400 | | | 0 | | | | | | 800 | 2.62 | 85.14 | 1.87 | 3.74 | 85.49 | 10.74 | 4.08 | 85.66 | 21.01 | 4.95 | 85.74 | 31.88 |
| | | 400 | | | | 100 | | 0 | | | | 2.77 | 85.14 | 2.03 | 3.81 | 85.49 | 10.80 | 4.13 | 85.66 | 21.05 | 4.96 | 85.74 | 31.90 |
| | | 400 | | | | 100 | | | 200 | | | 2.81 | 85.14 | 2.07 | 3.83 | 85.49 | 10.82 | 4.14 | 85.66 | 21.06 | 4.97 | 85.74 | 31.91 |
| | | 400 | | | | 100 | | | | 400 | | 2.85 | 85.14 | 2.10 | 3.84 | 85.49 | 10.84 | 4.15 | 85.66 | 21.07 | 4.97 | 85.74 | 31.91 |
| | | 400 | | | | 100 | | | | | 800 | 2.92 | 85.14 | 2.18 | 3.88 | 85.49 | 10.87 | 4.17 | 85.66 | 21.09 | 4.98 | 85.74 | 31.92 |
| | | 400 | | | | | 50 | 0 | | | | 2.62 | 85.14 | 1.87 | 3.74 | 85.49 | 10.73 | 4.08 | 85.66 | 21.01 | 4.95 | 85.74 | 31.88 |
| | | 400 | | | | | 50 | | 200 | | | 2.66 | 85.14 | 1.91 | 3.76 | 85.49 | 10.75 | 4.10 | 85.66 | 21.02 | 4.96 | 85.74 | 31.89 |
| | | 400 | | | | | 50 | | | 400 | | 2.70 | 85.14 | 1.95 | 3.78 | 85.49 | 10.77 | 4.11 | 85.66 | 21.03 | 4.95 | 85.74 | 31.89 |
| | | 400 | | | | | 50 | | | | 800 | 2.77 | 85.14 | 2.03 | 3.81 | 85.49 | 10.80 | 4.13 | 85.66 | 21.05 | 4.96 | 85.74 | 31.90 |
| | | | 700 | | 0 | | | 0 | | | | 2.55 | 84.50 | 2.44 | 3.72 | 85.10 | 11.10 | 4.07 | 85.40 | 21.26 | 4.94 | 85.55 | 32.07 |
| | | | 700 | | 0 | | | | 200 | | | 2.59 | 84.50 | 2.49 | 3.74 | 85.10 | 11.11 | 4.08 | 85.40 | 21.26 | 4.95 | 85.55 | 32.08 |
| | | | 700 | | 0 | | | | | 400 | | 2.63 | 84.50 | 2.53 | 3.75 | 85.10 | 11.13 | 4.09 | 85.40 | 21.27 | 4.95 | 85.55 | 32.08 |
| | | | 700 | | 0 | | | | | | 800 | 2.71 | 84.50 | 2.61 | 3.79 | 85.10 | 11.17 | 4.12 | 85.40 | 21.29 | 4.96 | 85.55 | 32.09 |
| | | | 700 | | | 100 | | 0 | | | | 2.86 | 84.50 | 2.76 | 3.86 | 85.10 | 11.23 | 4.15 | 85.40 | 21.33 | 4.98 | 85.55 | 32.11 |
| | | | 700 | | | 100 | | | 200 | | | 2.90 | 84.50 | 2.80 | 3.87 | 85.10 | 11.25 | 4.16 | 85.40 | 21.34 | 4.99 | 85.55 | 32.12 |
| | | | 700 | | | 100 | | | | 400 | | 2.93 | 84.50 | 2.83 | 3.89 | 85.10 | 11.27 | 4.17 | 85.40 | 21.35 | 4.99 | 85.55 | 32.12 |
| | | | 700 | | | 100 | | | | | 800 | 3.00 | 84.50 | 2.90 | 3.92 | 85.10 | 11.30 | 4.19 | 85.40 | 21.37 | 5.00 | 85.55 | 32.13 |
| | | | 700 | | | | 50 | 0 | | | | 2.71 | 84.50 | 2.61 | 3.79 | 85.10 | 11.17 | 4.11 | 85.40 | 21.29 | 4.96 | 85.55 | 32.09 |
| | | | 700 | | | | 50 | | 200 | | | 2.75 | 84.50 | 2.65 | 3.81 | 85.10 | 11.18 | 4.12 | 85.40 | 21.30 | 4.97 | 85.55 | 32.10 |
| | | | 700 | | | | 50 | | | 400 | | 2.79 | 84.50 | 2.69 | 3.82 | 85.10 | 11.20 | 4.14 | 85.40 | 21.31 | 4.97 | 85.55 | 32.10 |
| | | | 700 | | | | 50 | | | | 800 | 2.86 | 84.50 | 2.76 | 3.86 | 85.10 | 11.24 | 4.16 | 85.40 | 21.33 | 4.98 | 85.55 | 32.11 |
| | | | | 1400 | 0 | | | 0 | | | | 2.77 | 83.01 | 4.17 | 3.83 | 84.20 | 12.11 | 4.14 | 84.80 | 21.92 | 4.99 | 85.10 | 32.56 |
| | | | | 1400 | 0 | | | | 200 | | | 2.81 | 83.01 | 4.21 | 3.85 | 84.20 | 12.12 | 4.15 | 84.80 | 21.93 | 4.99 | 85.10 | 32.57 |
| | | | | 1400 | 0 | | | | | 400 | | 2.85 | 83.01 | 4.24 | 3.87 | 84.20 | 12.14 | 4.16 | 84.80 | 21.94 | 5.00 | 85.10 | 32.57 |
| | | | | 1400 | 0 | | | | | | 800 | 2.92 | 83.01 | 4.32 | 3.90 | 84.20 | 12.17 | 4.18 | 84.80 | 21.96 | 5.01 | 85.10 | 32.58 |
| | | | | 1400 | | 100 | | 0 | | | | 3.06 | 83.01 | 4.46 | 3.96 | 84.20 | 12.24 | 4.22 | 84.80 | 22.00 | 5.02 | 85.10 | 32.60 |
| | | | | 1400 | | 100 | | | 200 | | | 3.09 | 83.01 | 4.49 | 3.98 | 84.20 | 12.25 | 4.23 | 84.80 | 22.01 | 5.03 | 85.10 | 32.61 |
| | | | | 1400 | | 100 | | | | 400 | | 3.13 | 83.01 | 4.52 | 3.99 | 84.20 | 12.27 | 4.24 | 84.80 | 22.02 | 5.03 | 85.10 | 32.61 |
| | | | | 1400 | | 100 | | | | | 800 | 3.19 | 83.01 | 4.58 | 4.02 | 84.20 | 12.30 | 4.26 | 84.80 | 22.04 | 5.04 | 85.10 | 32.62 |
| | | | | 1400 | | | 50 | 0 | | | | 2.92 | 83.01 | 4.32 | 3.90 | 84.20 | 12.17 | 4.18 | 84.80 | 21.96 | 5.01 | 85.10 | 32.58 |
| | | | | 1400 | | | 50 | | 200 | | | 2.96 | 83.01 | 4.36 | 3.91 | 84.20 | 12.19 | 4.19 | 84.80 | 21.97 | 5.01 | 85.10 | 32.59 |
| | | | | 1400 | | | 50 | | | 400 | | 2.99 | 83.01 | 4.39 | 3.93 | 84.20 | 12.21 | 4.20 | 84.80 | 21.98 | 5.01 | 85.10 | 32.59 |
| | | | | 1400 | | | 50 | | | | 800 | 3.06 | 83.01 | 4.46 | 3.96 | 84.20 | 12.24 | 4.22 | 84.80 | 22.00 | 5.02 | 85.10 | 32.60 |

* Output = A(change in size/1 million) + B(DO-1.6) + C(86-temp.) Size multiplier (A) = 1.00 DO Multiplier (B) = 1.00 Temp. Multiplier (C) = 1.00

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# Formulating and evaluating aquatic habitat outputs

- Results
  - Changing outputs did not alter cost-effective plan ID.
  - Increasing inflow, then recirculation, then bottom aeration was preferable to excavation
  - Increasing inflow was the first-best way to increase aquatic habitat.

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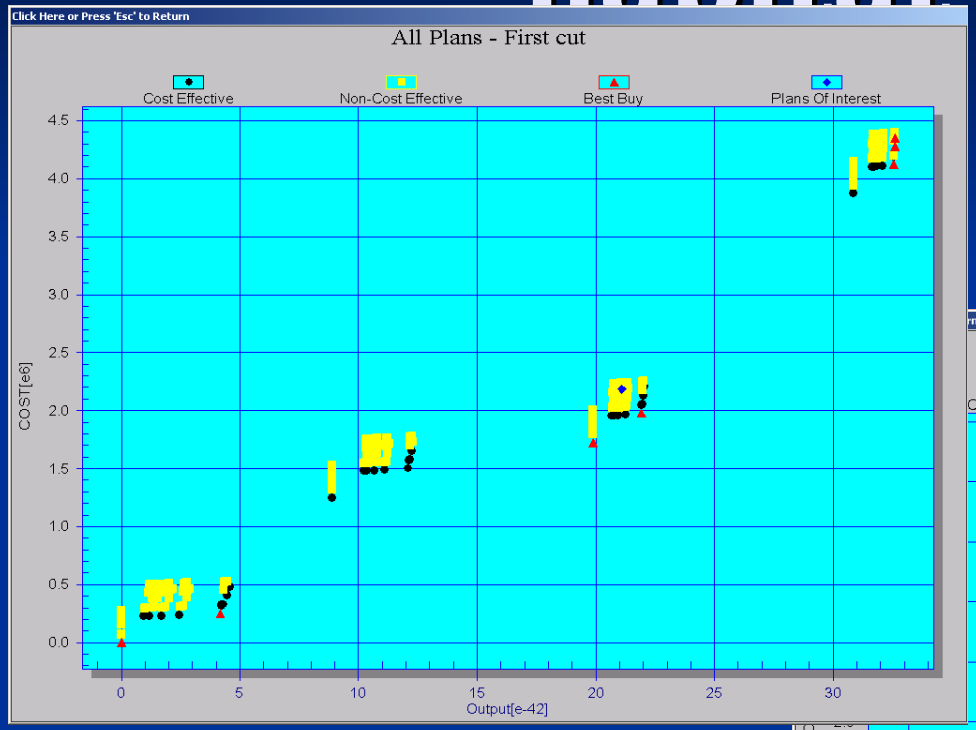
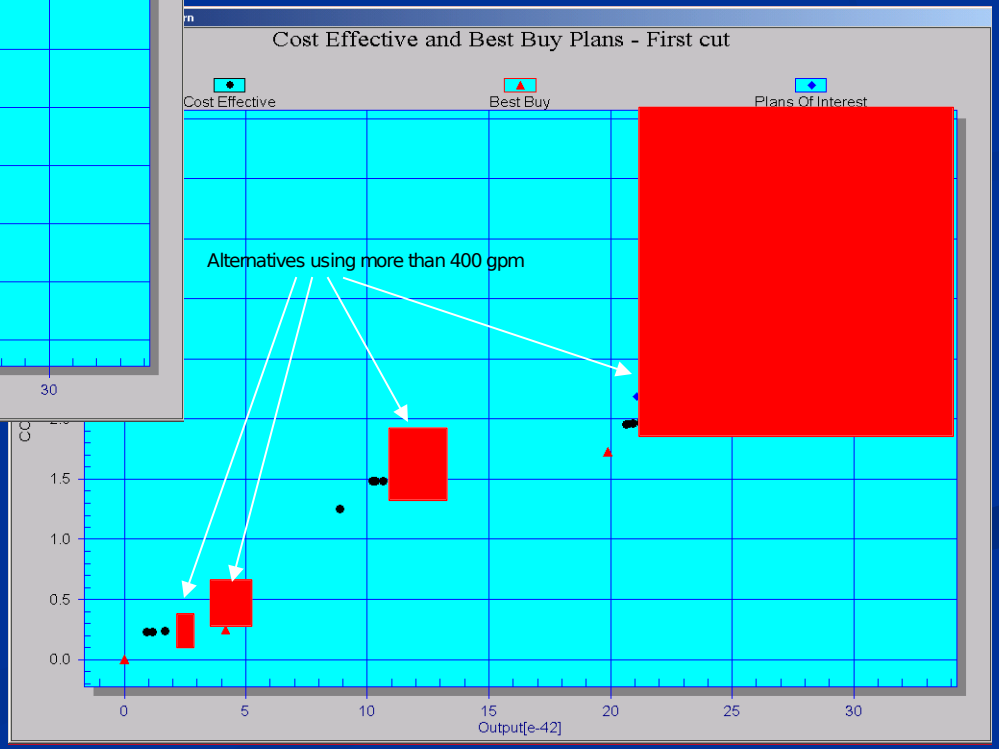
# Formulating and evaluating aquatic habitat outputs



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# Formulating and evaluating wetland habitat outputs

- Wetland Habitat Goals
  - Wetland habitat modeled as an externality of the aquatic habitat.
  - Use 48 available acres
- Management Measures Considered
  - Deep marsh, Shallow marsh, Wet meadow
  - Each habitat will spill water into the next habitat as another externality
  - Riparian habitat constructed to fill out the remaining acreage.
- Outputs Developed
  - Habitat Units (HU), developed in-house
  - Mixed-type HUs were preferable to monotype HUs

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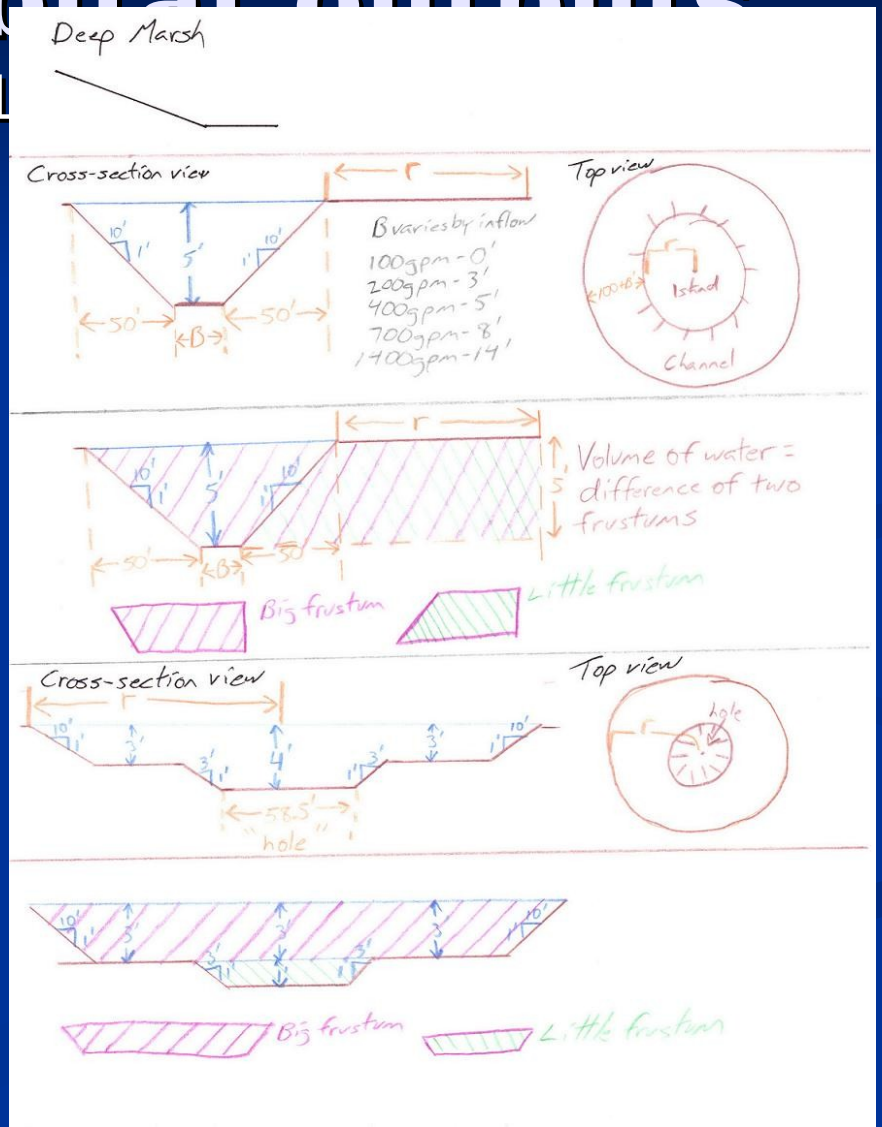
# Formulating and evaluating wetland habitat outputs

What's a frustu



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# Formulating and evaluating wetland habitat outputs

- Results
  - Deep marshes were not efficient/effective ways to generate output until they are components in a mixed-environment plan.
  - Increasing inflow was, again, a cost-effective way to increase HU output.

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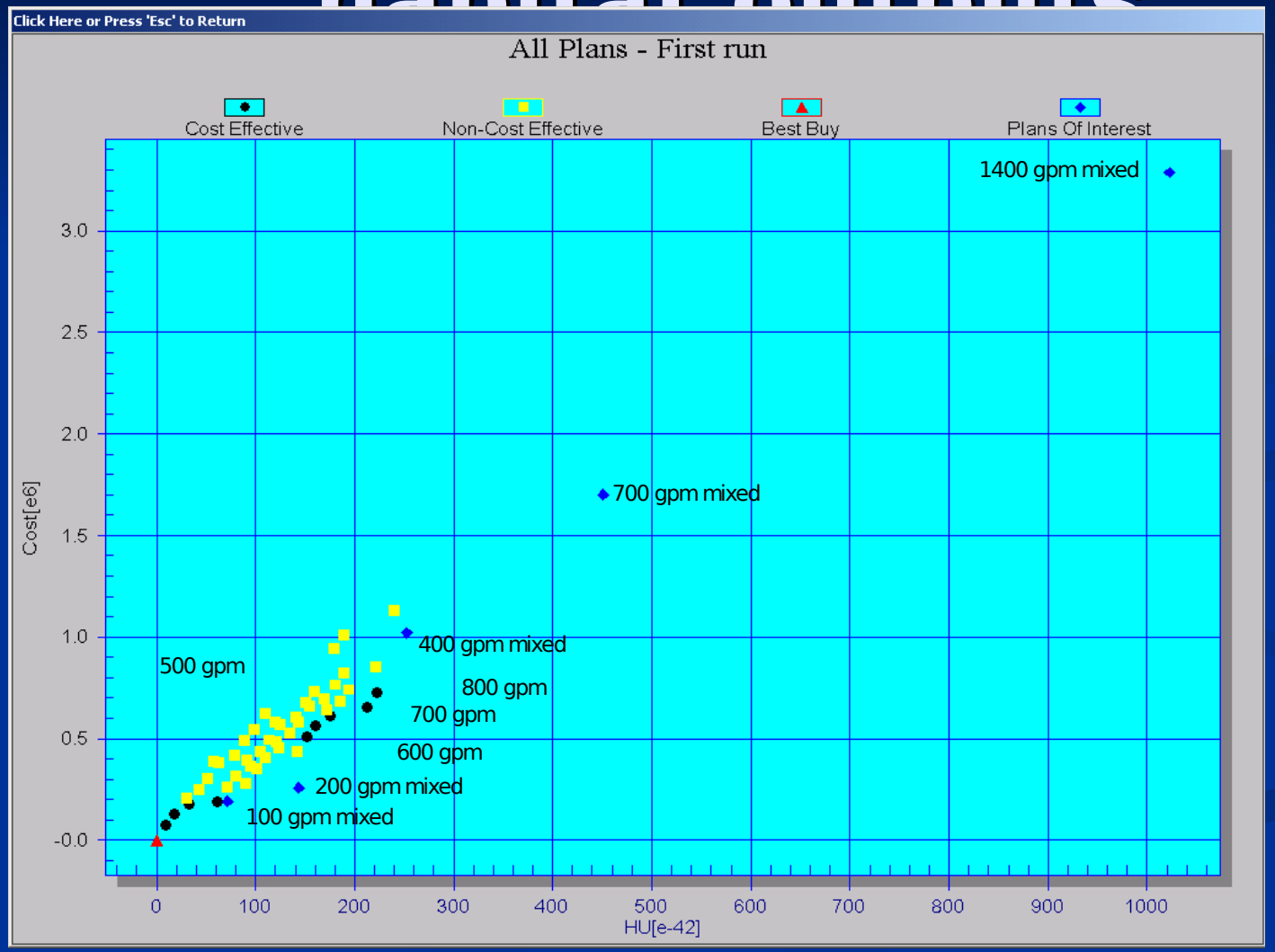
# Formulating and evaluating wetland habitat outputs



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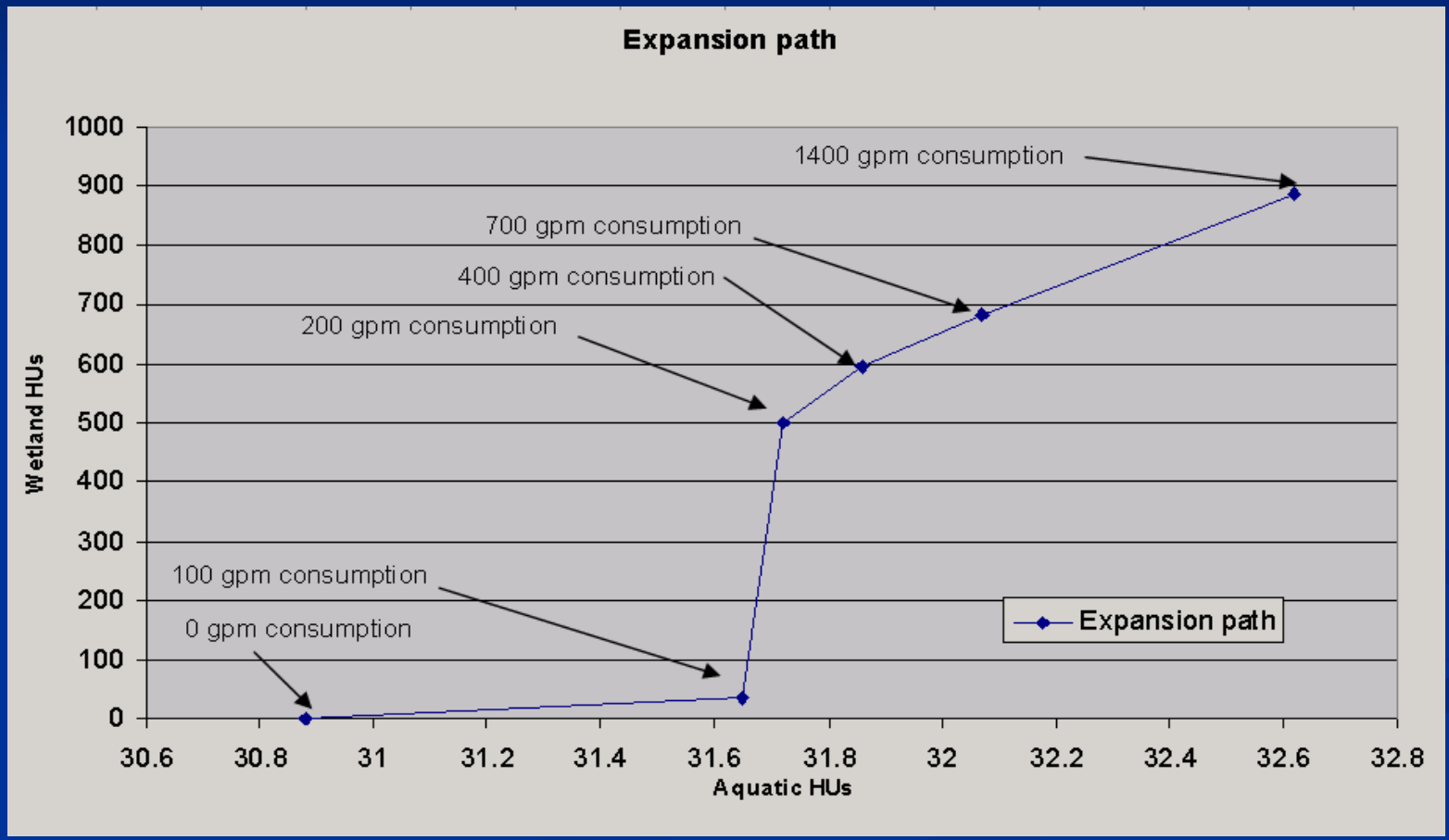
# Tradeoff Analysis



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# Before

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# After

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# Lessons Learned

- Economics time and cost estimate insufficient for this.
  - Essentially this was ***two*** CE/ICA runs and a tradeoff analysis.
- IWR-PLAN was not well-equipped to handle complementary goods.
  - Aquatic habitat measures and outputs were analyzed 5 separate times (1 day of data entry each time).
  - Wetland habitat measures were to be a function of [48 acres – (Deep marsh acres + Shallow Marsh Acres + Wet Meadow acres)] = Riparian Habitat acres
- Env. team member involvement critical in setting up each IWR-PLAN run. (Is IWR-PLAN telling the story you want it to tell?)

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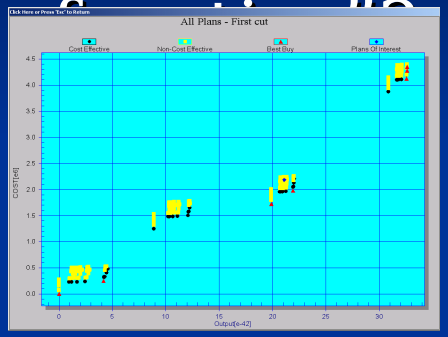
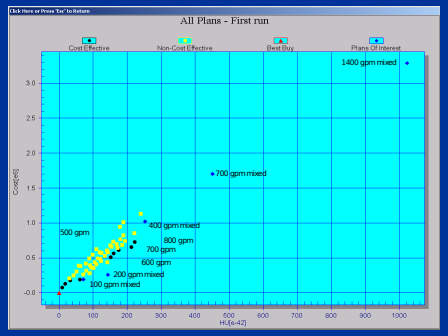
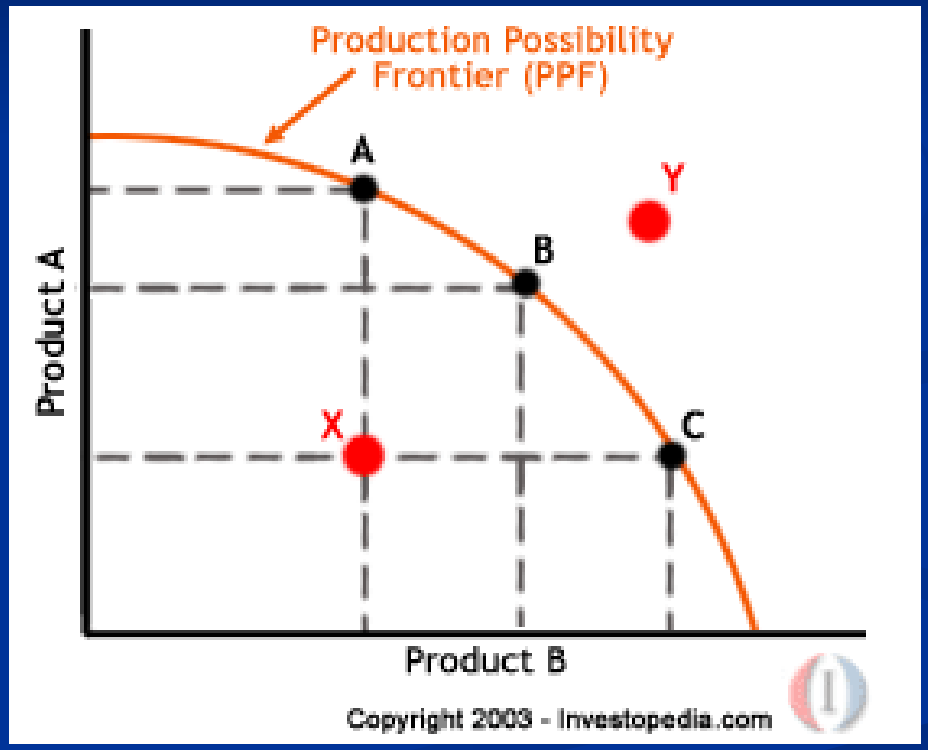
# How many fish for that tree?

- Remember “production possibility




- Ask an economist, they’re clever folks!